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Prospects for the Upgraded Tevatron

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Abstract

Plans and prospects for the next Fermilab collider running period, Run II (beginning in 1999), are described. The upgrades to the accelerator are discussed in the context of expected achievable instantaneous and integrated luminosity. Upgrades to the two collider detectors, CDF and DØ, along with physics potential for Run II are also described. Options for Fermilab beyond Run II are mentioned.

1 Introduction

The recent discovery of the top quark[1, 2] along with > 100 other publications have shown that the Fermilab Tevatron and the two collider experiments, CDF and DØ, are extremely successful in the production of fundamental physics results. For the next ten years Fermilab will be unique in its ability to produce the top quark and, until LEP 200, the W boson. The top quark discoveries were based on data collected during Run Ia (1992-1993, $\approx 20 \text{ pb}^{-1}$) and part of Run Ib (1994-present, $\approx 60 \text{ pb}^{-1}$). Run Ib is scheduled to end in July 1995 and an additional 50 pb^{-1} is expected to be delivered by that time.

In January 1999 Fermilab will begin what is called Run II, the first run with the Main Injector. Run II will see at least an order of magnitude increase in the instantaneous luminosity over current levels and an integrated luminosity of roughly 1 fb^{-1} per year is expected. Both the CDF and DØ collaborations are planning major detector and data acquisition upgrades to take full advantage of the high intensity running. Both experiments have focused their upgrades on the detection of top quark events with improvements in b -tagging and lepton identification. The large data samples available in Run II will allow precise measurements of the top and W masses as well as many other fundamental parameters. The upgrades to the accelerator will be described in Section 2. The upgrades to the CDF and DØ detectors are discussed in Section 3 and in References [3, 4]. The physics programs for Run II are described in Section 4 and in Reference [4] for DØ and Reference [5] for CDF.

2 Accelerator Upgrades for Run II

The Fermilab complex is comprised of the Antiproton accumulator and 4 accelerators: the Linac (0-0.4 GeV), the Booster (0.4-8 GeV), the Main Ring (8-150 GeV), and the Tevatron (150-1000 GeV). Upgrades to each of the systems have contributed to the growth in luminosity since the first collisions were observed in 1985. Table 1 shows the luminosity for previous runs of the Tevatron and the projection to Run II.

In the '88-'89 Run, the luminosity was limited by the beam-beam tune shift which occurred as the proton and antiproton beams passed through each other. Before Run Ia electrostatic separators were installed in the Tevatron. This put the beams on helical orbits with a 5σ separation and reduced the number of the proton and antiproton beam crossings from 12 to 2. The beam-beam tune shift was thus reduced and higher intensity beams in the Tevatron were possible. In addition, improvements were made to the \bar{p}

	88-89	Run Ia	Run Ib	Run II	Units
CM energy	1800	1800	1800	2000	GeV
p/bunch	7.0	12	20	24	$\times 10^{10}$
\bar{p} /bunch	2.9	3.1	5	3-5	$\times 10^{10}$
Number of Bunches	6	6	6	36 (99)	
Total \bar{p}	1.7	18.6	30	108-180	$\times 10^{10}$
\bar{p} stacking rate	2.0	4.0	6.0	17	$\times 10^{10} \bar{p}/\text{hour}$
Bunch spacing	3500	3500	3500	396 (132)	nsec
Interactions/crossing	0.3	0.9	3	3	
Peak Luminosity	0.16	0.9	1.76	10-20	$\times 10^{31} \text{cm}^{-2} \text{sec}^{-1}$
Integrated Luminosity	4 pb^{-1}	20 pb^{-1}	110 pb^{-1}	1 $\text{fb}^{-1}/\text{year}$	
What's New	-	Separators \bar{p} Upgrade	Linac Booster	Main Injector \bar{p} Upgrade	

Table 1:

Evolution of accelerator parameters and performance. In Run II the number of bunches will start at 36 which corresponds to a 396 nsec spacing between bunches. Shown in parentheses is a possible Run II upgrade which would reduce the number of interactions per crossing.

source which resulted in increased \bar{p} production and lower \bar{p} emittance. Between Runs Ia and Ib, the Linac and Booster were upgraded. The Linac now delivers higher energy (400 MeV instead of 200 MeV) and higher intensity beams to the Booster. The Booster more efficiently accelerates and transfers the beam to the Main Ring. These improvements have led to record numbers of protons at collision and record production of antiprotons. As of this conference, the \bar{p} stacking record was $6.68 \times 10^{10} \bar{p}/\text{hour}$ and the highest instantaneous luminosity was $1.76 \times 10^{31} \text{cm}^{-2} \text{s}^{-1}$, almost twice the record in Run Ia. The record integrated luminosity was $3.8 \text{pb}^{-1}/\text{week}$.

In Run Ib, the luminosity of the Tevatron is limited primarily by the number of antiprotons available for collisions. Fermilab is currently building a new ring, the Main Injector, to replace the existing Main Ring. The Main Injector will have a larger aperture and higher efficiency for transferring antiprotons to low beta. Also, the intensity of the beam available for antiproton stacking will be increased from about 3 to 5×10^{12} . Stacking rates of $17 \times 10^{10} \bar{p}/\text{hour}$ are expected. Another advantage of the Main Injector is that it is tangent to the Tevatron, rather than in the same tunnel. This will significantly reduce the amount of background radiation in the experimental halls and will make it possible to gain access to the Main Injector while $p\bar{p}$ collisions are occurring in the Tevatron.

Main Injector construction is already in progress. Two thirds of the Main Injector

Figure 1: The number of interactions per crossing is shown as a function of instantaneous luminosity for different numbers of bunches.

tunnel had been completed at the time of this conference. Connections to the existing accelerators will occur during scheduled lab shutdowns. The booster will be connected to the Main Injector this summer, July - Oct. '95. The connection to the Tevatron will be made during a nine month shutdown just prior to Run II.

As the instantaneous luminosity increases, so do the chances of having multiple interactions in a single crossing. Multiple interactions complicate analysis of the data by creating more background particles in each event. To reduce this effect, the number of bunches in Run II will be 36, rather than the 6 bunches used in Run I. Figure 1 shows the number of interactions per crossing as a function of instantaneous luminosity for different number of bunches. Later in Run II, if the luminosity increases above 10^{32} it is possible that the number of bunches will be increased to 99 to keep the number of interactions per crossing at around three or less. The reduced spacing between crossings, 396 ns with 36 bunches or 132 ns with 99, presents technical challenges which CDF and DØ are currently addressing.

Additional upgrades for Run II include an improved \bar{p} cooling system, target sweeping to avoid \bar{p} target destruction, lower β^* (25 cm instead of 35 cm at the interaction regions), and an increase in the beam energy to 1 TeV. A summary of the Run II parameters is shown in Table 1.

An 8 GeV \bar{p} storage ring is also being considered for the Main Injector Project. This ring would be installed in the Main Injector tunnel. It would be used to recycle \bar{p} 's from

the Tevatron at the end of a $p\bar{p}$ store and to store \bar{p} 's after they are produced in the accumulator. Electron cooling would be used to produce extremely intense \bar{p} beams.

With the planned upgrades, the accelerator is expected to reach a luminosity of $>1 \times 10^{32} cm^{-2} s^{-1}$ in the first year of Run II and to deliver $1 fb^{-1}$ by the year 2000.

3 Detector Upgrades

The CDF and DØ collaborations are planning upgrades to their detectors and data acquisition systems to take advantage of the high luminosity running in Run II. The upgrades build on the experience with the current detectors and are focused primarily on increasing the acceptance for top, other high p_t phenomena and B -physics.

3.1 CDF Upgrades

The CDF detector has been observing $p\bar{p}$ collisions at Fermilab for roughly ten years and the detector and collaboration have evolved along with the increasing luminosity of the accelerator. For CDF to operate with the reduced bunch spacings and high interactions rates of Run II, major upgrades to the front end electronics, the forward calorimetry and the tracking systems are required. The CDF upgrades are briefly described below. More details are available in Reference [3]. Figure 2 shows a comparison of the Run I and Run II CDF detectors.

3.1.1 CDF Upgrades: Calorimetry

The existing CDF calorimeter is comprised of two distinct technologies: the central calorimeter ($|\eta| < 1.1$) which uses scintillators with phototube readout, and the plug and forward gas calorimeters ($1.1 < |\eta| < 4.2$). The gas calorimeters are too slow for operation with 132 ns bunch spacings. The upgrade replaces the plug and forward calorimeters with a more compact scintillating tile system. The light in each tile is read out by wavelength shifting fibers and phototube technology. As shown in Figure 2, the new plug extends to lower angles than the existing plug, and thus replaces the functionality of the forward calorimeter. The new electromagnetic calorimeter contains an embedded position detector at shower maximum to improve electron identification and π/γ separation. The calorimeter upgrade is roughly 70% complete.

Figure 2: Schematic of the CDF detector configurations in Run I and Run II. Note that in Run II the scintillating tile plug calorimeter replaces the plug and forward gas calorimeter combination of Run I and Forward Muon system is moved closer to the central region.

3.1.2 CDF Upgrades: Tracking

CDF is currently planning a staged approach to the tracking upgrades for Run II. For the beginning of Run II, the Silicon Vertex detector (SVX) and the Vertex Time Projection chamber (VTX) will be replaced. Roughly two years into the run, or when the luminosity exceeds 10^{32} , a new Central Tracking Chamber (CTC) will be installed.

The new silicon vertex detector (SVX II) will be similar to the previous SVX in geometrical design but will be almost twice as long (96 cm) as the existing SVX (51 cm). SVX II will have 5 instead of 4 concentric layers. The inner layer will be at a radius of $R = 2.4$ cm and the outer layer will be located at $R = 10.7$ cm. SVX II will have 3 separate barrels with readout at both ends of each barrel, and will use double sided detectors for 3D track reconstruction. SVX II readout will have a 42 cell analog pipeline and will support either 396 or 132 ns between bunch crossings. The pipeline will support simultaneous digitization and readout of the data while additional data is entering the pipeline (SVX 3 chip). This permits a high level 1 accept rate (50 kHz) with minimal deadtime. High speed readout (6-7 μs) is also necessary in order to use the SVX II data in the Level 2 trigger. A Silicon Vertex Trigger (SVT) system is being constructed. The SVT will provide impact parameter information for the Level 2 trigger decision. The impact parameter resolution of the SVX II will be $\approx 15 \mu m$.

Outside the SVX, but inside the Central Tracking Chamber (CTC), a fiber tracking system will replace the current Vertex Time Projection chamber. The fiber tracker is constructed of 6 concentric layers and covers $R = 18 - 27$ cm. Each layer consists of a doublet layer of 0.5mm diameter fibers, spaced by 0.6 mm and staggered layer to layer by a half spacing. The 0.5 mm fiber will provide an $r\text{-}\phi$ resolution of order $100\mu m$ compared to the Central Tracking Chamber resolution of $\approx 200 \mu m$ per wire. The fiber tracker will use Visible Light Photon Counter (VLPC) readout and supply track stub information to the Level 1 trigger. Together the SVX II and the fibers will provide stand alone tracking in the region $|\eta| < 2.0$.

The Muon system will be improved by completing the coverage in ϕ and adding more scintillators to the trigger system. The Forward Muon system will move closer to the central region, changing the eta range covered from 2.0-3.6 to 1.5-3.0. The electronics for all the muon systems will be modified for operation in the 36-99 bunch environment.

3.1.3 CDF Upgrades: Trigger and Data Acquisition

The goal of the CDF trigger and DAQ system is to have a livetime greater than 90% at an instantaneous luminosity of about 2×10^{32} . To achieve this goal CDF will have a pipelined three level trigger system. The Level 1 trigger will be deadtimeless meaning a Level 1 decision will be made before the pipeline buffer is full. The pipeline will be 42 crossings deep and have a $5.5 \mu sec$ latency. The Level 1 trigger will make decisions based on calorimeter, muon hits, fiber and central tracking information.

The Level 2 trigger is designed to accommodate a maximum of 50 kHz input rate. Level 2 will be buffered and pipelined. It will use the Alpha processors which are already operating in Run Ib. The silicon vertex track processor and impact parameter information will provide a very powerful trigger for b -physics.

The third level of the trigger is a Silicon Graphics computer farm. It is currently operating in Run Ib with 3200 MIPs and can handle an input rate of about 40Hz. For Run II the CPU power of Level 3 will be increased to about 20 kMips and have a maximum input rate of about 300-500 Hz. The maximum output rate from Level 3 will be about 20 Hz.

3.2 DØ Upgrades

The DØ collaboration has a substantial upgrade plan for Run II. The primary upgrade to the DØ detector is a new central tracking system, incorporating a 2 Tesla solenoid magnet. The present drift chambers will be replaced by a silicon vertex detector and a fiber tracking system inside the magnetic field. Preshower detectors will be installed in the central and forward regions to improve photon and electron ID. The trigger and front end electronics will be upgraded to cope with the 132ns bunch spacing. These upgrades are briefly presented below and are described in detail in Reference [4].

3.2.1 DØ Upgrades: Tracking

The inner tracking chambers of DØ will be entirely replaced by the solenoid, a silicon vertex detector and a fiber tracking system. Figure 3 shows the inner tracking volume of DØ with the Run II detectors. The solenoid will be 2.8m long and have an average inner radius of 0.6m. The expected resolution of the silicon + fiber system in the solenoidal field is $\delta p_T/p_T^2 \approx 0.002$.

The DØ silicon vertex detector, SVX, is constructed of interleaved barrels and disks and provides 3D tracking information. There are 7 barrel segments along the beamline (z direction). Each barrel is 6 cm long and constructed of 4 concentric layers. The inner radius of the silicon barrels is 2.6 cm and the outer radius is 10 cm. Layers 1 and 3 are single sided detectors, and layers 2 and 4 are double sided. Two types of disks will be used in conjunction with the barrels. There will be 12 small diameter disks, $R = 2.6 - 10$ cm, in the central region. Six will be located at $z = \pm 6.4, \pm 19.2$ and ± 32 cm interleaved with the barrels. Six more of the small disks will be located at $z = 44.8$ cm, 49.8 cm, and 54.8 cm. Four large disks, $R = 9.5 - 26$ cm, will be positioned at $z = \pm 100$ cm and ± 120 cm. The small disks will be double sided (30° stereo) and the large disks will be single sided (15° stereo). The silicon will provide tracking in the region $|\eta| < 3.0$. Readout of both the SVX and the fiber tracker (described below) will be accomplished with the SVX2 chip. The SVX2 chip has 32 stages of analog pipeline delay and is designed to accept data every 132 ns. This allows $4.2\mu\text{sec}$ for the Level 1 trigger decision. Testing of prototypes and radiation damage studies are in progress.

A fiber tracking system will be installed outside the silicon detector, but still within the solenoidal field. This device will be 4 cylinders of four-fiber doublets at average radii of 20, 30, 40 and 50 cm. When combined with the SVX, the fiber tracker will provide a momentum measurement of all charged particles within $|\eta| < 1.7$. The fiber tracker will

angle=-90

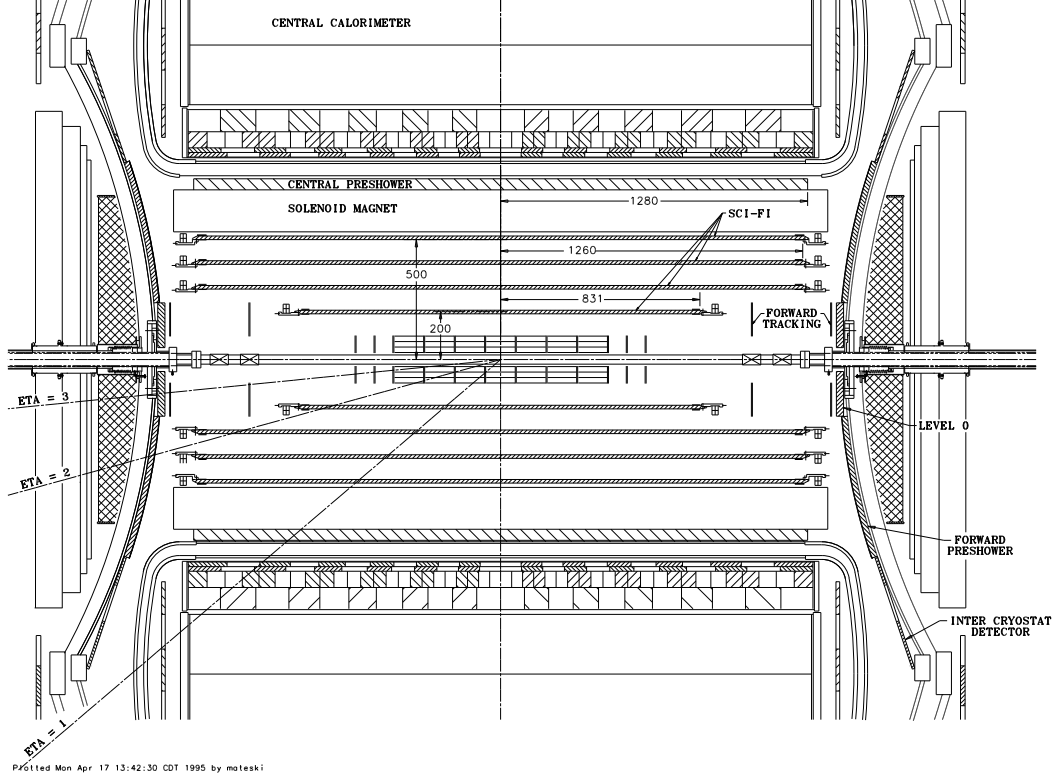


Figure 3: Inner tracking region of the Run II DØ detector.

also provide fast track information for the Level 1 electron and muon triggers.

The fiber tracker will be constructed of multiclاد scintillating fiber. The outer diameter of a fiber is $830 \mu m$ and the inner core is $770 \mu m$. The system will use Visible Light Photon counters (VLPC) for photodetection. Cryogenic cassettes are being designed and tested. A cosmic ray test of a 3 layer system was performed at Fermilab in May-December 1994 with excellent results[4].

The muon chambers at DØ will remain essentially the same as in Run Ib, but the front end electronics will be upgraded for the 132 ns bunch spacing. Because the drift time in the muon chambers exceeds the beam crossing interval in Run II, additional fast scintillator detectors will be added to time-stamp muon tracks. These detectors will also be used to provide a muon trigger covering up to $|\eta| \sim 2.5$ for single muons with $p_T \geq 6 - 10 \text{ GeV}/c$ and dimuons with $p_T \geq 1.5 - 2 \text{ GeV}/c$. The upgraded detector will benefit from greatly improved muon momentum resolution compared with the present DØ muon system, by the use of the central magnetic field to momentum-analyze muon tracks.

3.2.2 DØ Upgrades: Calorimeter

The main upgrade to the DØ liquid argon calorimeter will be to adapt the front end electronics for the Run II bunch spacings. Electron ID will be improved in both the central and forward regions with the addition of preshower detectors. These will have 5mm scintillator strips and also use VLPC readout.

3.2.3 DØ Upgrades: Trigger and Data Acquisition

The DØ trigger/DAQ system will be modified so as to become fully buffered. The Level 1 trigger will have calorimeter, muon and fiber tracking information. The Level 2 trigger will also be buffered. It will have information from the preshower detector and use tighter matching cuts between the tracking information and the electron or muon information. The upgrades are quite modest, so the bandwidth remains limited to 5–10 kHz for L1 accepts, 800 Hz for L2 accepts and 10 Hz for Level 3 accepts [4].

4 Physics in Run 2

The upgrades to the CDF and DØ detectors are designed to enhance the physics capacity of the experiments as well as allowing them to operate in the high luminosity (and short bunch spacing) environment. This section will describe the expected improvements in top and W mass measurements and list a few of the other topics that will be covered in Run II.

4.1 Top

Both CDF and DØ have published results on the discovery of the top quark [1, 2]. Both experiments detect the top decay to $W + b$ where at least one of the W 's decays semileptonically. The presence of a b quark is established by the identification of a secondary vertex or by the presence of a soft lepton from the b decay. According to Monte Carlo estimates [6], roughly 80% of the leptons or b 's are within $|\eta| < 1.0$ and 100% are within $|\eta| < 2.4$. To improve the acceptance and efficiency for top identification, the upgrades of both experiments have concentrated on improving the lepton ID and the b -tagging in the $|\eta| < 2.4$ region. In Run II, CDF and DØ will have roughly equivalent capability for tagging b 's from top decays [6]. The upgrades also significantly improve the capabilities for

electroweak, exotic, QCD and B -physics. A comparison of Run Ib and Run II b -tagging and top acceptance is presented below for the CDF detector.

Monte Carlo studies indicate that roughly 97% of the b -quark decay products will be found in the fiducial region of the SVX II detector. The tagging efficiency for a fiducial b -jet will be approximately 60% in Run II, compared to 35% ($|\eta| < 2.4$) in Run Ib[6]. This increase is due primarily to the longer detector (96 cm instead of 51 cm) and from the decrease in the number of fake tracks due to the 3D tracking information. Lepton tagging at CDF will improve from 10% to roughly 13% due to improvements in the lepton ID in the plug ($1 < |\eta| < 2.4$) region. With these upgrades, the efficiency for tagging a single b in a $t\bar{t}$ event will improve from 52% to roughly 85% and the efficiency for tagging two b 's in a $t\bar{t}$ event will increase from 13% to 42% [6].

For CDF, the total acceptance for $t\bar{t}$ to lepton + 3 jets + b is 5% in Run Ib and will increase by a factor of 2 in Run II. For a top mass of 175 GeV and the theoretical cross section at 2 TeV of 6.8 pb[6], CDF expects roughly 700 tagged top events per fb^{-1} . The time scale for this size sample is one year after the beginning of Run II. Table 2 shows the Run Ib and Run II acceptances and the expected number of events[5] with 2 fb^{-1} .

In the top mass analysis, the presence of a 4th jet is required which reduces the acceptance slightly as shown in Table 2. By the year 2001, 2 years into Run II, CDF and DØ will each have roughly 1200 events in their top mass analysis. Each experiment will also have roughly 600 doubly tagged events. An alternative mass analysis might use the doubly tagged events and thus eliminate much of the combinatoric confusion in the standard mass analysis.

The uncertainty on the top mass can be estimated for the 2 fb^{-1} event samples from the current analysis. The statistical error on the top mass is expected to scale as $1/\sqrt{N}$ which would be about 1 GeV. The largest systematic uncertainties depend on primarily on our modeling of the events. This will improve as large samples of high p_T W , Z and photon data become available. For example, the effect of gluon radiation on the jet energy scale can be checked by looking at the p_T balancing in $Z + 1$ jet events. With 50 pb^{-1} of Run Ib data this sample has a statistical precision of 5%. As shown in Table 2 CDF expects to have roughly 27k $Z+1$ jet events which would translate to a statistical precision of about 1% and an uncertainty on the top mass of about 2 GeV. Similarly, most of the systematic uncertainties scale with $1/\sqrt{N}$ because the high statistics samples will provide better constraints on the Monte Carlos. Another way to estimate or reduce the effect of the jet energy scale uncertainty on the top mass is to reconstruct the dijet mass for the two jets assigned to the W decay. With the upgraded detectors and 2 fb^{-1} of data

Channel	Acceptance, A_{IB} (Run Ib)	Acceptance, A_{II} (Run II)	# of Events (w/ A_{Ib})	# of Events (w/ A_{II})
Produced $t\bar{t}$	-	-	13600	13600
Dileptons ($ee, \mu\mu, e\mu$)	0.85%	1.1%	115	140
lepton+ $\geq 3j$	9.5%	12%	1300	1700
lepton+ $\geq 3j$ w/ ≥ 1 b tag	5.1%	10.5%	690	1400
lepton+ $\geq 4j$	8.2%	11%	1100	1500
lepton+ $\geq 4j$ w/ ≥ 1 b tag	4.3%	9.1%	600	1200
lepton+ $\geq 4j$ w/ 2 b tags	1.1%	4.5%	150	610
W+ $\geq 1j$	0.45%	0.60%	200k	270k
W+ $\geq 4j$	$1.2 \times 10^{-3}\%$	$1.5 \times 10^{-3}\%$	500	700
Z+ $\geq 1j$	0.45%	0.60%	20k	27k
Z+ $\geq 4j$	$1.2 \times 10^{-3}\%$	$1.5 \times 10^{-3}\%$	50	70

Table 2:

Acceptance and yield of $t\bar{t}$ events for the Run II CDF detector. The yield is determined using the theoretical cross section (6.8 pb) at $M_{top} = 175$ GeV/c² and $\sqrt{s} = 2$ TeV. In addition the number of expected W/Z-plus-jet events is shown. For comparison, the acceptances for Run Ib are shown along with the expected yield with 2 fb⁻¹. The acceptances include branching ratios and leptonic and kinematic selection (*e.g.* jet counting).

a precision of 4 GeV on the top mass[4, 5] should be possible.

With the large data samples of Run II it will also be possible to determine many of the fundamental production and decay properties of the top quark. Precision measurements of the top cross section, and branching ratios will be pursued along with measurements of the angular distributions, top width, and a measure of $|V_{tb}|$. The $t\bar{t}$ system is also a an excellent probe for physics beyond the standard model.

4.2 Electroweak Physics

Another goal of the Run II physics program is the study of electroweak parameters of the standard model. Direct measurement of both the top and W mass are currently unique to the Tevatron and provide fundamental information about the standard model and the mass of the Higgs. Measurements of W width and leptonic branching ratios, and the W and Z trilinear couplings also provide sensitive tests of new physics. A nice summary with projections into the future has been compiled by the DPF Electroweak Working Group[7].

This paper will review the W mass analysis at CDF[8] and the projection to 2 fb^{-1} of data in Run II.

In Run II, CDF and DØ each expect to collect 0.2-0.3 million W events for the W mass analysis. CDF and DØ have found that most of the systematic uncertainties in the W mass scale with $1/\sqrt{N}$ [5]. For example, at CDF, the number of events in the J/ψ sample determines the uncertainty in the calibration of the central tracking chamber. Tables 3 and 4 show the published uncertainty on the W mass from CDF and the extrapolation to 2 fb^{-1} with the Run II detector.

Source of Uncertainty	Uncertainty (MeV/c ²)		
	$W \rightarrow e\nu$	$W \rightarrow \mu\nu$	Common
Statistical	145	205	—
Lepton Energy/Momentum Scale	120	50	50
Lepton Energy/Momentum Resolution	80	60	—
Recoil modeling	60	60	60
Trigger, Event Selection	25	25	—
Backgrounds	10	25	—
Theoretical Model	75	75	65
Fitting	10	10	—
Total Uncertainty	230	240	100
e and μ Combined Uncertainty	180		

Table 3: Summary of uncertainties in the Run Ia CDF W mass measurement.

As shown in Table 4, at CDF the uncertainty on the W mass will be reduced to roughly 40 MeV. Similarly DØ estimates an uncertainty on the W mass of 50 MeV. The W mass and the top mass constrain the mass of the Higgs. Figure 4 shows the top and W mass uncertainty and the resulting range of allowed Higgs masses estimated for 2 fb^{-1} of data in Run II.

4.3 QCD, B -Physics and New Phenomena searches in Run II

QCD measurements such as the W and Z plus jets multiplicities, b content of jets, the photon cross section and the contribution of gluons at low x will become more precise

Source of Uncertainty	Uncertainty (MeV/c ²)		
	$W \rightarrow e\nu$	$W \rightarrow \mu\nu$	Common
Statistical	14	20	—
Lepton Energy/Momentum Scale	20	15	15
Lepton Energy/Momentum Resolution	8	6	—
Recoil modeling	6	6	6
Trigger, Event Selection	10	10	—
Backgrounds	5	10	—
Theoretical Model	30	30	30
Fitting	5	5	—
Total Uncertainty	42	40	34
e and μ Combined Uncertainty	38		

Table 4: Estimate of uncertainties in the CDF W mass measurement for 2 fb⁻¹.

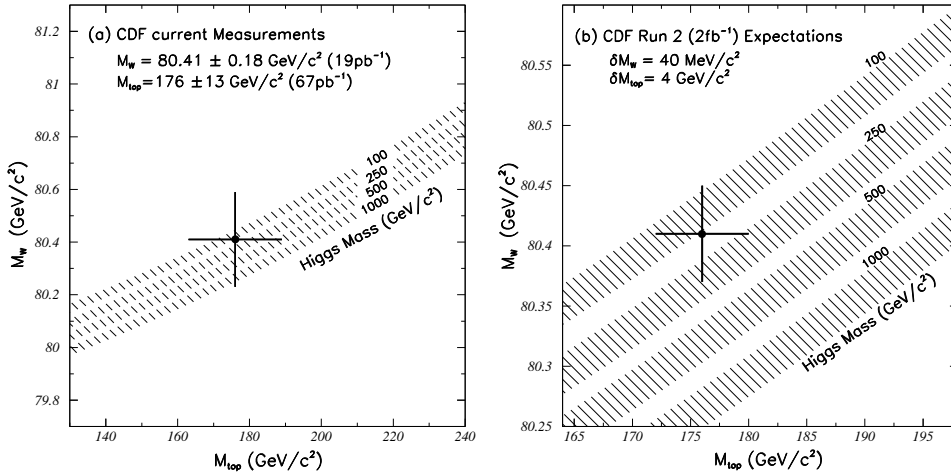


Figure 4: The data point in the left figure represents the CDF measurements of M_W and M_{top} , and the point in the right figure represents the CDF estimate for 2 fb⁻¹. The curves are from a calculation [9] of the dependence of M_W on M_{top} in the minimal standard model using several Higgs masses. The bands are the uncertainties obtained by folding in quadrature uncertainties on $\alpha(M_Z^2)$, M_Z , and $\alpha_s(M_Z^2)$.

with the addition of more luminosity. Tighter constraints on the Parton Distribution Functions will come from the analysis of the W asymmetry and a measurement of α_s over the largest E_T range ever in a single experiment will be possible.

The limits and discovery potential for new phenomena simply increase with increasing integrated luminosity. Run II will provide an excellent opportunity to extend the current searches and embark on quests for new particles such as W' , Z' , and compositeness.

The increased b -tagging capability of both experiments will clearly enhance the B -physics program at the Tevatron. Sensitive tests of the unitarity of the CKM matrix and the standard model origin of CP violation will be possible in Run II. For example, in Run II with 2 fb^{-1} of data CDF projects a sensitivity to CP violation of $\delta\sin 2\beta \approx 0.07$ and $\delta\sin 2\alpha \approx 0.10$ and to B_s mixing for $x_s < 20$. These and other projections for Run II are described in References [4, 5].

5 Beyond Run II

Fermilab is considering a number of options for the far future, after Run II. They include a super luminous Tevatron with $L > 10^{33}$, a Muon collider, a large linear e^+e^- collider, and polarized proton beams. The physics potential and feasibility of the options are under investigation. A decision or reduced list is expected by the end of the summer of 1996.

6 Conclusions

The Fermilab Tevatron is unique in its opportunities to study top quark production, electroweak physics, B -physics and for searches beyond the standard model. Run II, the Main Injector project, will provide high luminosity and a rich environment for physics. Some of the exciting physics topics which will be possible with the large data samples of Run II have been described along with the planned collider detector upgrades. Run II is expected to begin in January 1999. Both experiments eagerly look forward to upgrading the detectors and to the wealth of data of Run II.

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References

- [1] F. Abe *et. al.* (CDF Collaboration), Phys. Rev. D **50**, 2966 (1994); F. Abe *et. al.* (CDF Collaboration), Phys. Rev. Lett. **73**, 225 (1994). F. Abe *et. al.* (CDF Collaboration), Phys. Rev. Lett. **74**, 2626 (1995).
- [2] S. Abachi *et. al.* (DØ Collaboration), Phys. Rev. Lett. **74**, 2632 (1995).
- [3] *The CDF Upgrade* CDF Note 3171.
- [4] *The DØ Upgrade* DØ Note 2542.
- [5] *Physics with CDF in Run II* CDF Note 3172.
- [6] *Report of the Tev2000 Study Group on Future Electroweak Physics at the Fermilab Tevatron* CDF Note 3177, DØ Note 2589.
- [7] F. S. Merritt, H. Montgomery, A. Sirlin and M. Swartz, DPF report on Precision Tests of Electroweak Physics, CDF Note 3154.
- [8] F. Abe *et. al.* (CDF Collaboration), Accepted for publication in Phys. Rev., FERMILAB-PUB-95/033-E.
- [9] The curves are calculated using a FORTRAN program from F. Halzen and B.A. Kniehl (private communication), described in Nucl. Phys. **B353**, 567 (1990).